Acoustic Imaging Microscope

The Idaho National Laboratory has developed a Laser Ultrasonic Microscope, which allows for full field real-time imaging of micro sized devices. The high speed visualization results in performance optimization in manufacturing of consumer micro-devices, which has direct application in the telecommunications industry, medical industry, surveillance industry, and anywhere were the evaluation of vibration patterns are needed.

Acoustical Microscopy can be performed using laser ultrasonics by feeding both the generation and detection optical beams through the microscope objective. The figure shows a microelectronic circuit where a pulsed or chopped laser beam thermoelastically heats a local region (focused to around 10 micron diameter).

A second laser beam detects the local surface ultrasonic motion by interferometric detection (either with passive or active interferometers). Surface waves (Rayleigh) and bulk waves (longitudinal) can be observed traveling through the microelectronic circuit allowing for various nondestructive evaluation measurements of film thickness, substrate bonding, substrate flaws, etc.

Sensitivities of 6x10-4 nm @ 880 MHz have been demonstrated with over 4 orders of magnitude dynamic range using 532 nm optical wavelength. A calibration curve was obtained using a piezoelectric generator and the optical detection using lock-in phase sensitive methods. The source laser can be focused to about 1-2 microns diameter providing for generation and detection at frequencies of 1 GHz. At GHz frequencies, the acoustical wavelengths are on the order of a few microns. This wave propagation in material microstructures at the individual grain level.

Competing technologies utilize interferometric methods and provide a “point and shoot” single point measurement capability. In order to perform measurements over a large surface, the laser generation and detection spots must be scanned in a raster fashion over the area, recording ultrasonic signals at each location.

In contrast, the INL Laser Ultrasonic Camera employs a photorefractive (adaptive) approach to interferometry to provide full-field real-time images of ultrasonic motion over large areas. The measured ultrasonic motion of the surface, is impressed onto the phase of the detection laser beam, just as with

Feature	*INL RT-AIM*	*Competitive Advantage*
Speed	275K/sec*	>1000 times faster
Range	0.1 nm - 50 nm **	Displacement vs. Velocity
Spatial Resolution	1 um	High resolution needed for MEMS
Frequency Response	2 GHz***	MEMS=>micron wavelengths
Microscopic	YES	MEMS=>micron dimensions
Cost	Low	No Scanning

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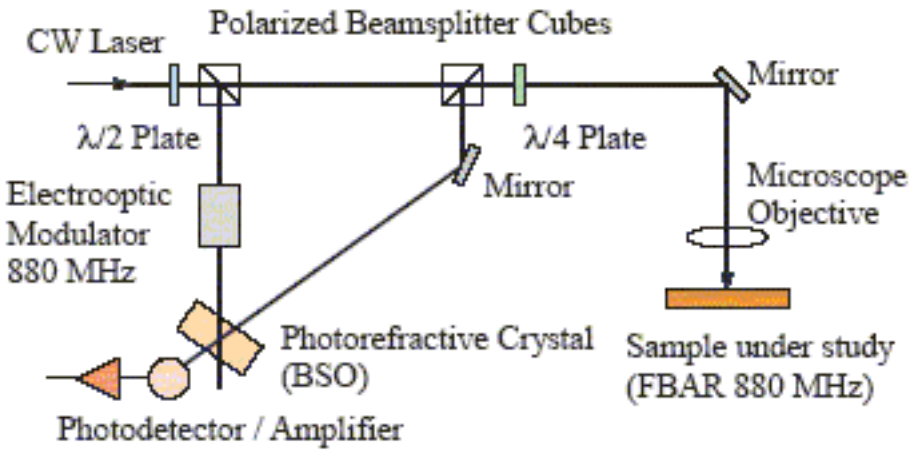

Figure 1: Narrowband Optical Detection Schematic.

the other passive methods. The entire optical image of the vibrating surface is formed inside the photorefractive material where it undergoes real time processing due to the dynamics of the photorefractive process. Nonlinear optical mechanisms within the photorefractive recording material are utilized to produce an output image that is a "picture" of the vibrating surface or subsurface. The net effect is that interferometric detection is accomplished over the entire vibrating surface all at once without scanning, producing an output that can be viewed directly with the eye or with a television camera. No additional electronic or computational processing is required! By eliminating the need for scanning over large areas or complex parts, the inspection process is sped up.

Benefits

An optical microscope has been modified to incorporate INL acoustic imaging technology, allowing for:

- normal microscopic illumination and image capture
- dynamic holographic imaging produces a map of the vibrational motion
- real time visualization of micron acoustic wave length phenomena

INL's acoustic imaging technology also provides:

- Unique dynamic holo graphic approach, which allows operation at any frequency from H to GHz, 0.1nm acoustic displacement sensitivity, supports single point and scanned measurements at subpi - cometer displacement sensitivity, and video frame rates (20 Hz)
- Software for presentation of data as images (3D and 2D), interactions between adjacent regions are clearly shown, provides animations that further clarify the meaning of data and relationships between parts
- Full-field images of acoustical motion at video frame rates
- A greater savings in time and much higher spatial resolution of the measurement
- Sensitivity suitable for most applications
- A means of imaging acoustical motion in microscopic (MEMS) devices

Partnering with INL

INL's goal is to find a party interested in commercializing this technology. The INL has several patents on the process. See U.S. Patent Nos. 5,827,971, 6,134,006, 6,175,411, 6,486,962, and 6,401,540. See also published U.S. Patent Application Nos. 10/267,320, 10/267,237. The INL invites interested parties to contact us regarding licensing details.

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